CLAIMS

1. A hollow membrane comprising two support layers (5a, 5b) arranged one above the other creating between them a space and a plurality of capillary tubes (3) arranged between the two support layers and each having an opening at the level of each of the support layers in such a way as to form capillary channels for the flow of a first fluid, the space between the capillary tubes and the two support layers forming an internal cavity (7) for circulation of a second fluid around the capillary tubes, the two support layers and the capillary tubes being constituted by an organic polymer.

2. A hollow membrane according to Claim 1, in which the organic polymer is a heterocyclic polymer or a polyacetylene.

3. A hollow membrane according to Claim 2, in which the heterocyclic polymer is a polypyrrole, a polyaniline or a polythiophene.

4. A hollow membrane according to any one of Claims 1 to 3, in which the capillary tubes have a length of from 1 to 1000 µm, preferably from 5 to 60 µm, an internal diameter of from 0.02 to 50 µm, preferably from 0.1 to 10 µm, and a wall thickness of from 0.01 to 10 µm, preferably from 0.1 to 3 µm.

5. A hollow membrane according to any one of Claims 1 to 4, in which the capillary tubes (3) are arranged substantially perpendicular to the two support layers (5a, 5b) or along directions that form an angle at the most 45° with the perpendicular to the two support layers.

6. A hollow membrane according to any one of Claims 1 to 5 comprising from 10^4 to 8×10^9 capillary tubes per cm^2, preferably from 10^5 to 5×10^8 capillary tubes per cm^2 of support layer.

7. A method of manufacturing a hollow membrane according to any one of Claims 1 to 6 comprising the following steps :

a) forming on the external surfaces and in the pores of a membrane matrix (1), that includes open rectilinear pores (3) arranged between its two external surfaces, a coating of organic polymer (5) by in situ polymerization of a precursor monomer of the polymer, and

b) then removing the material forming the membrane matrix by destruction in a selective reactant which does not affect the polymer in order to form the internal cavity of said hollow membrane.

8. A method according to Claim 7, in which the membrane matrix is made of a polymeric material or an inorganic material and in which the rectilinear pores of the membrane matrix have been created by irradiation using a beam of heavy ions, followed by dissolution of the material in the tracks formed by the ions and/or around them.

9. A method according to Claim 8, in which the polymeric material is chosen from among polycarbonates, polyethylene terephthalate, polyimides or polyvinylidene fluoride and the reactant is chosen from among the inorganic bases and acids.

10. A method according to Claim 8, in which the inorganic material is aluminum oxide and the reactant is chosen from among the inorganic bases and acids or

the inorganic material is mica and the reactant is hydrofluoric acid.

11. A method according to Claim 7, in which the polymerization is carried out in situ from the monomer precursor by chemical or electrochemical oxidation of said monomer.

12. A method according to Claim 11, in which the polymerization by chemical oxidation is carried out by bringing one face of the membrane matrix into contact with a solution of said monomer and the other face of the membrane matrix with a solution of an oxidizing agent.

13. A method according to any one of Claims 7, 11 and 12, in which so as to obtain different pore sizes in the walls of the capillary tubes, different degrees of wettability of said walls by aqueous solutions or by organic solvents, and/or different electro-conductivity properties, rigidity, porosity and/or flexibility, the organic polymer coating is subjected, during or after polymerization to treatment by

a) a reactant chosen from among the Lewis acids, particularly the alkyl, aryl or alkylaryl sulfonic acids or from among the salts of said acids, or

b) a reactant chosen from among the hydroxides or carbonates of alkali metals.

14. A fluid treatment module comprising at least one hollow membrane according to any one of Claims 1 to 6, arranged within a sealed enclosure in such a way as to provide, between two adjacent hollow membranes (11) and between each hollow membrane (11) and an adjacent side wall (17) of the enclosure, spaces (13) for the circulation of a first fluid uniquely in communication with the inside of the capillary tubes of the hollow

membrane or membranes, means (25, 27) of circulating said first fluid in the capillary tubes of the hollow membranes by introducing it into one of said circulation spaces and by collecting it in another of said circulation spaces and means (29, 31) of circulating at least one second fluid in the internal cavity or cavities of the hollow membrane or membranes (11).

15. A module according to Claim 14, in which the space or spaces (13) for circulation of said first fluid are filled with a lining that allows turbulence to be generated in the first fluid.

16. A module according to Claim 15, in which the lining is formed from a porous material, the pores of which have dimensions greater than the diameter of the capillary tubes.

17. A module according to Claim 16, in which the ratio of the dimension of the pores of the porous material to the diameter of the capillary tubes is from 5 to 200.

18. A module according to any one of Claims 16 and 17, in which the pores of the porous material are lined with a component chosen from catalysts, enzymes and sorbents that are insoluble in said first fluid, the ratio of the pore dimension of the porous material to the internal diameter of the capillary tubes remains within the range of from 5 to 50.

19. A module according to any one of Claims 14 to 18, comprising :

- a stack of n hollow membranes (11) and (n + 1) panels (13) of porous material alternating with the hollow membranes in such a way that each hollow membrane is positioned between two panels of porous

material, these panels forming spaces for the circulation of the first fluid,

- means (25, 27) of introducing the first fluid onto the lower or upper face of the stack and of recovering it at the opposite face of this stack,

- a chamber (19) for the introduction of the second fluid, arranged on a lateral face of the stack and in communication with the internal cavities of the hollow membranes (11), and

- a chamber (21) for receiving the second fluid arranged on the opposite lateral face of the stack and in communication with the internal cavities of said hollow membranes (11).

20. A module according to any one of Claims 14 to 18, comprising :

- a stack of n hollow membranes (11) and (n + 1) panels (13) of porous material alternating with the hollow membranes in such a way that each hollow membrane is positioned in a stack between two panels of porous material, these panels forming spaces for the circulation of the first fluid, the stack comprising a first series of hollow membranes with an odd number (11_1) and a second series of hollow membranes with an even number (11_2) arranged between the membranes with an odd number,

- means (59, 61) of introducing the first fluid onto the lower or upper face of the stack and of recovering it on the opposite face of this stack,

- a chamber (51) for the introduction of the second fluid, arranged on a first lateral face of the stack and in communication with the internal cavities of the hollow membranes (11_1) of the first series,

- a chamber (53) for receiving the second fluid arranged on the lateral face opposite to said first face and in communication with the internal cavities of said hollow membranes (11_1) of the first series,

- a chamber (55) for the introduction of a third fluid, arranged on the lateral face, called the second lateral face, contiguous with said first lateral face and in communication with the internal cavities of the hollow membranes (11_2) of the second series, and

- a chamber (57) for receiving the third fluid arranged on the lateral face opposite to said second face and in communication with the internal cavities of the hollow membranes (11_2) of the second series.

21. A module according to any one of Claims 14 to 18, comprising :

- a stack of n hollow membranes (11) and (n + 1) panels (13) of porous material alternating with the hollow membranes in such a way that each hollow membrane is positioned between two panels of porous material, these panels forming spaces for the circulation of the first fluid, the stack comprising a first series of hollow membranes with an odd number (11_1) and a second series of hollow membranes with an even number (11_2) arranged between the membranes with an odd number,

- means (59, 61) of introducing the first fluid onto the lower or upper face of the stack and of recovering it on the opposite face of this stack,

- a chamber (71) for the introduction of a second fluid, arranged on a first lateral face of the stack and in communication with the internal cavities of the hollow membranes (11_1) of the first series,

- a chamber (73) for receiving the second fluid arranged on the lateral face of the stack, called the second face and contiguous with said first face and in communication with the internal cavities of said hollow membranes (11_1) of the first series,

- a chamber (75) for the introduction of a third fluid, arranged on another lateral face of the stack, called the third face, and in communication with the internal cavities of the hollow membranes (11_2) of the second series, and

- a chamber (77) for receiving the third fluid arranged on the last lateral face of the stack, called the fourth lateral face, said chamber being in communication with the internal cavities of the hollow membranes (11_2) of the second series.

22. A module according to any one of Claims 19 to 21, in which the stack is arranged between two rigid grids (15) the openings in which are at least equal to or greater than the pore dimension of the panels of porous material.

23. A module according to any one of Claims 19 to 22, in which the diameter, the length and/or the quantity of capillary tubes of the hollow membranes in the stack are different in at least one hollow membrane of the stack.

24. A module according to Claim 23, in which the diameter of the capillary tubes reduces from one hollow membrane to the other in the direction of flow of the first fluid, and the density of capillary tubes increases from one hollow membrane to the other in the direction of flow of the first fluid.

25. A method of manufacturing a fluid treatment module according to any one of Claims 14 to 24 comprising the following steps :

1) Preparing at least one composite membrane (6) by forming, on the external surfaces and in the pores of a membrane matrix (1) comprising rectilinear open pores arranged between its two external surfaces, a coating (5) of organic polymer by in situ polymerization of a monomer precursor of the polymer,

2) Forming, from the composite membrane or membranes (6) and panels (13) of porous material, a stack in which each composite membrane (6) is arranged between two panels (13) of porous material,

3) Forming sealed joints (23) between the composite membranes and the porous panels on the lateral faces of the stack,

4) Making openings (24) in the sealed joint only at the level of the composite membranes, and for each composite membrane only on two different lateral faces of the stack,

5) Introducing through these openings a reactant capable of destroying the material forming the membrane matrix of the composite membranes without affecting the polymer covering the surfaces and the pores of the membrane matrix, in order to obtain a stack of hollow membranes (11) and panels (13) of porous material in which the internal cavities (7) of the hollow membranes are accessible on two lateral faces of the stack.

26. A method according to Claim 25, in which so as to obtain different pore sizes in the walls of the capillary tubes, different degrees of wettability of said walls by the aqueous solutions or by the organic solvents, and/or different electro-conductivity

properties, rigidity, porosity and/or flexibility, the coating of organic polymer is subjected, during or after polymerization to treatment by

a) a reactant chosen from among the Lewis acids, particularly the alkyl, aryl or alkylaryl sulfonic acids or from among the salts of said acids, or

b) a reactant chosen from among the hydroxides or carbonates of alkali metals.

27. A method according to either Claim 25 or 26, in which step 3) is carried out by causing the penetration of the adhesive into the porous panels and the composite membranes on the lateral faces of the stack.

28. A method according to Claim 27, comprising, in addition, a step of treating the panels of porous material, in order to facilitate the penetration of the adhesive, before carrying out step 3).